https://ntrs.nasa.gov/search.jsp?R=20180007407 2019-08-31T18:23:10+00:00Z

Power, Energy Storage and Conversion for Aircraft

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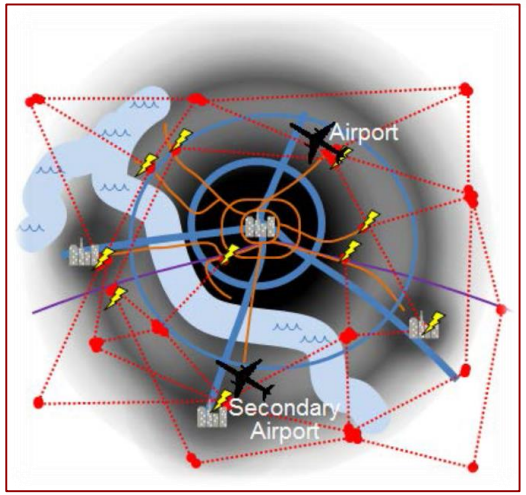
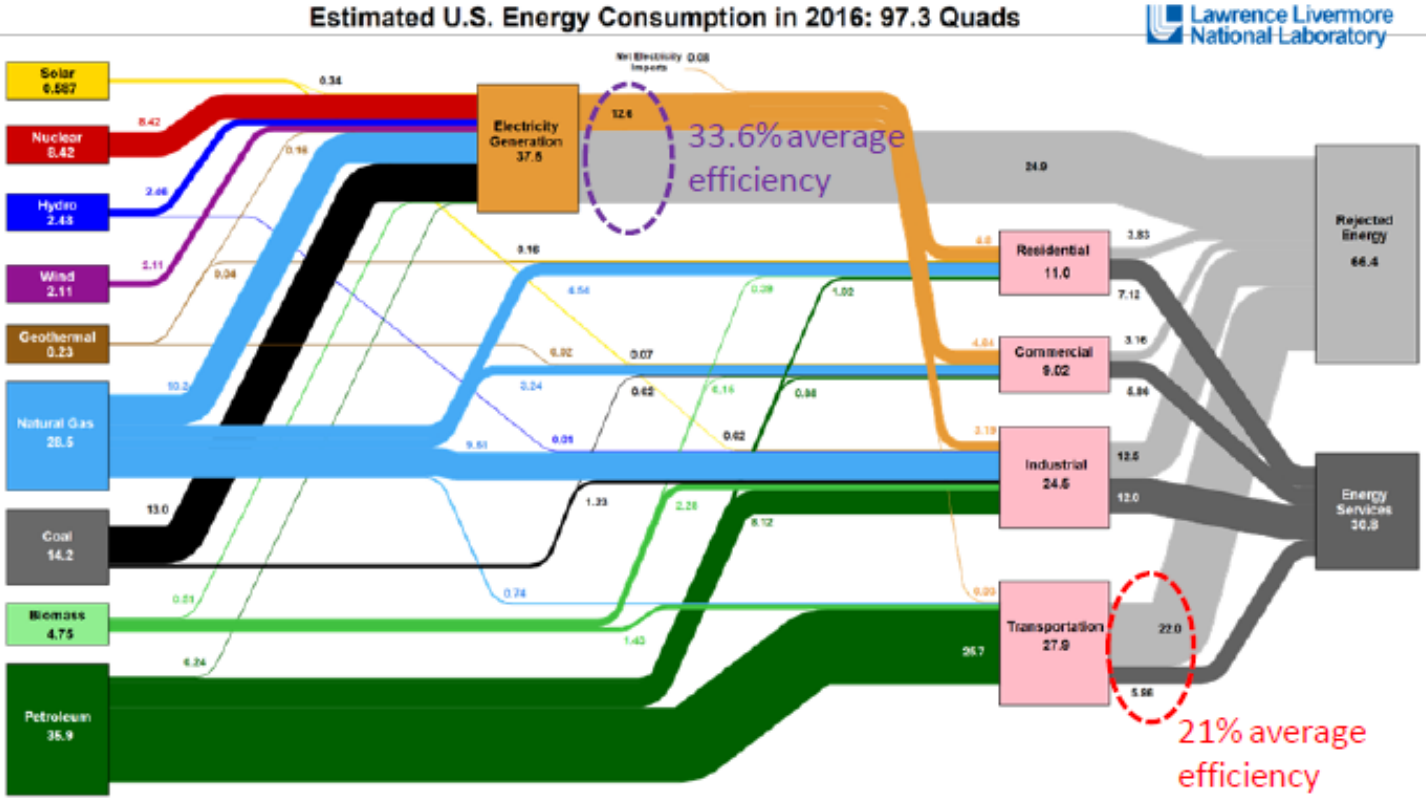
Electrically Enhanced Propulsion

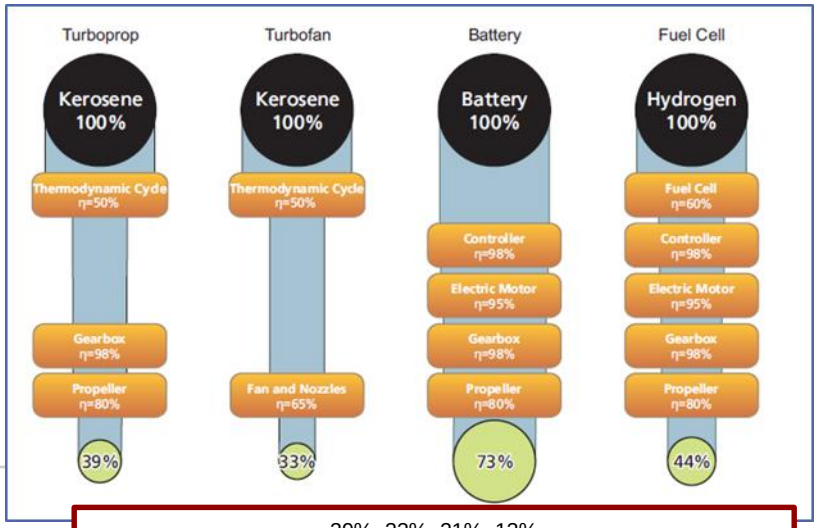
- Why electric?
  - Fewer emissions
  - Quieter flight
  - Fuel savings
  - New mobility options
  - Better utilization of infrastructure



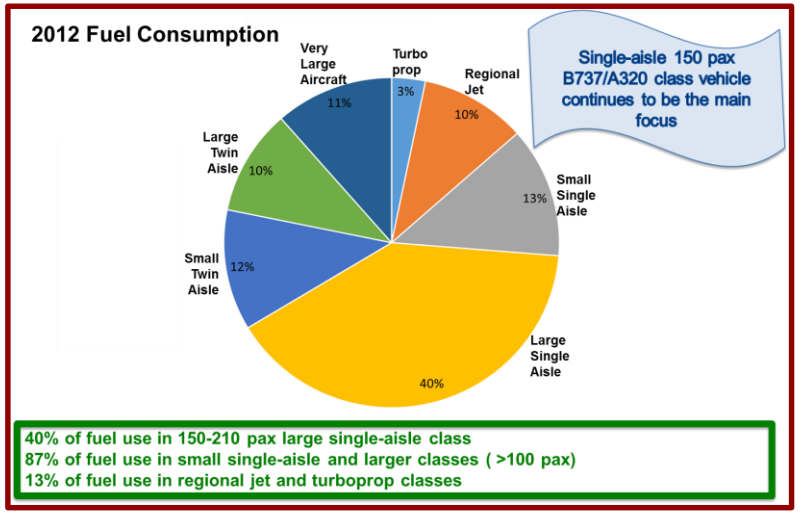
Energy Consumption

U.S. Energy Consumption & Waste, 2016





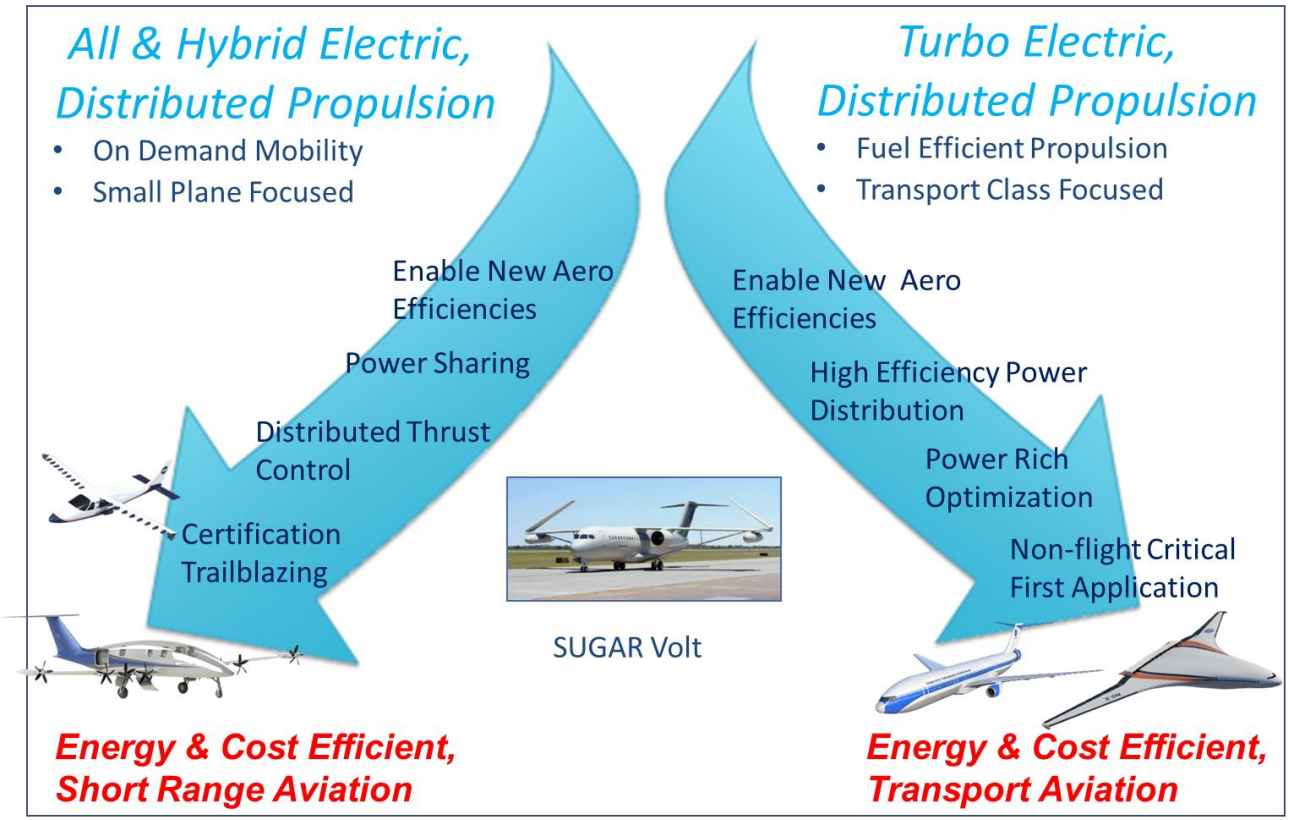
39%, 33%, 21%, 13%
Well to Wake



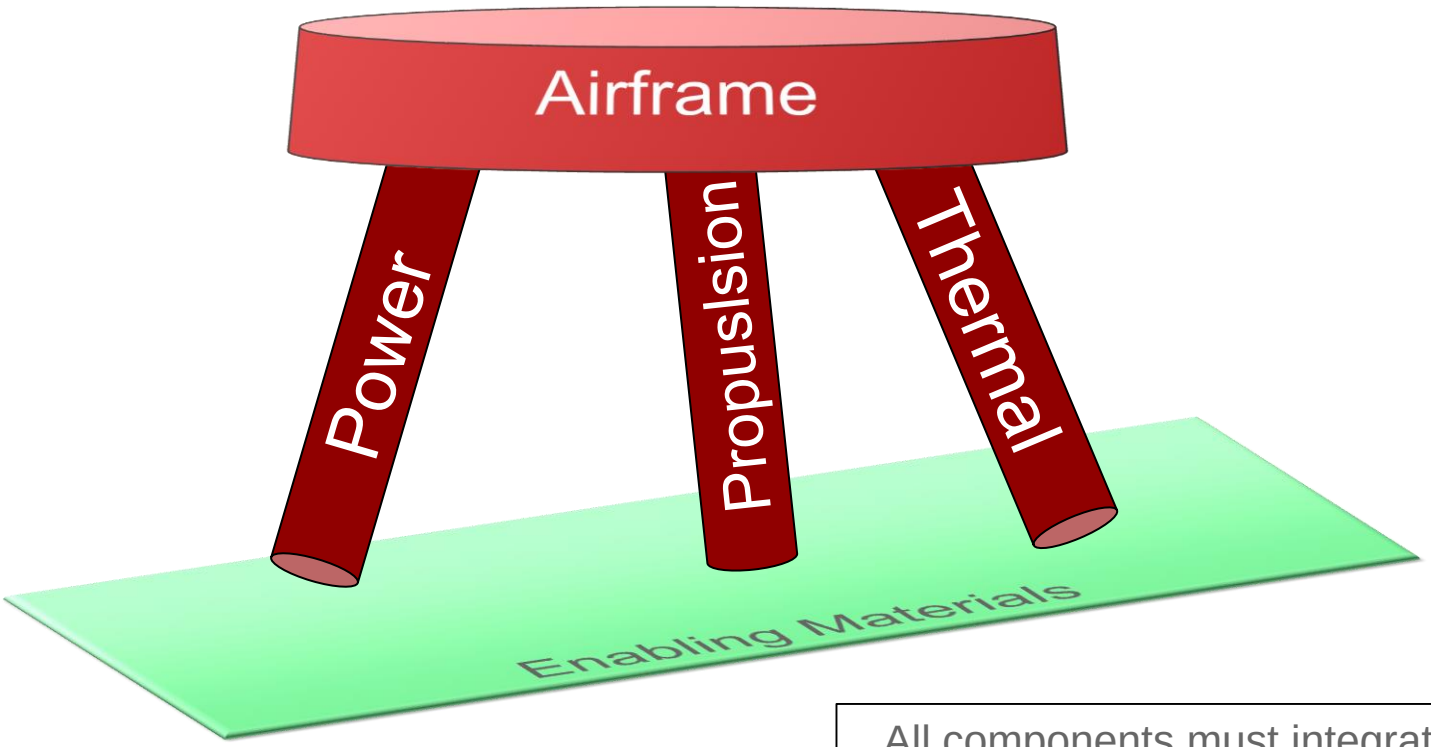
Vehicle Classes

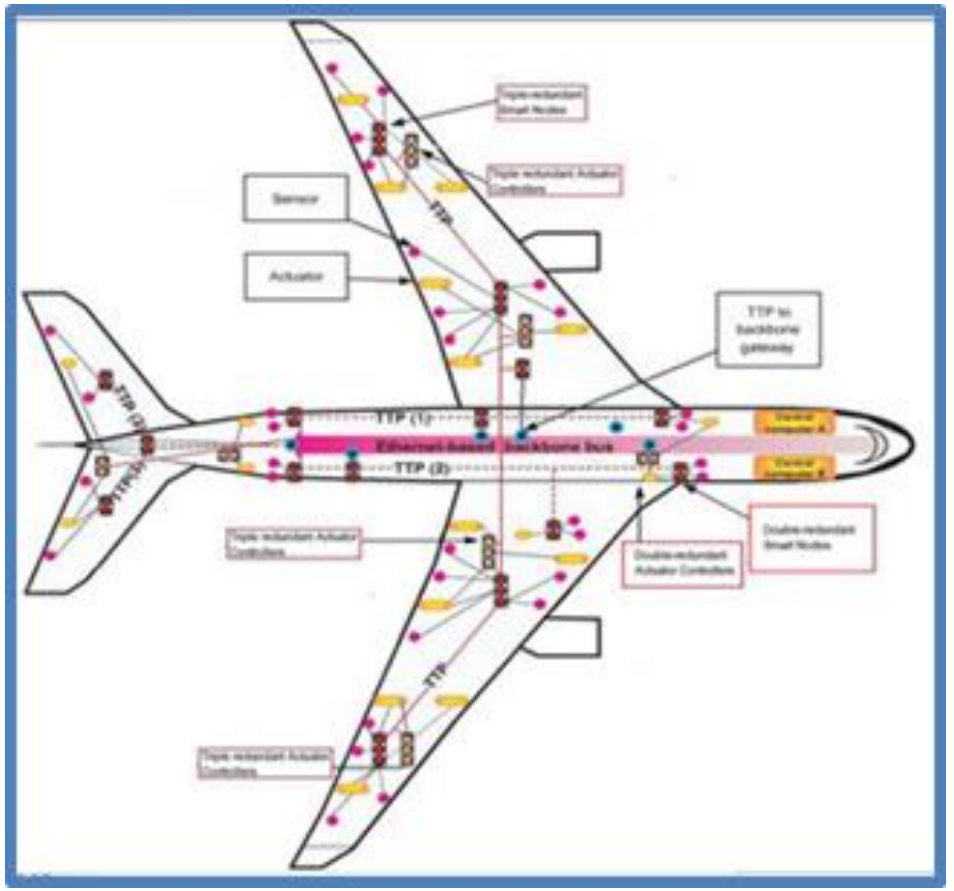
Unmanned Aerial Systems (UAS)
Personal Air Vehicles (PAV)
Logistic Delivery Vehicles (LDV) – <589 kg
Ultralight
General Aviation
Regional Jet
Single, Double-Aisle
Blended Wing Body, Truss-Braced Wing Body

VEHICLE CONFIGURATION EXAMPLES



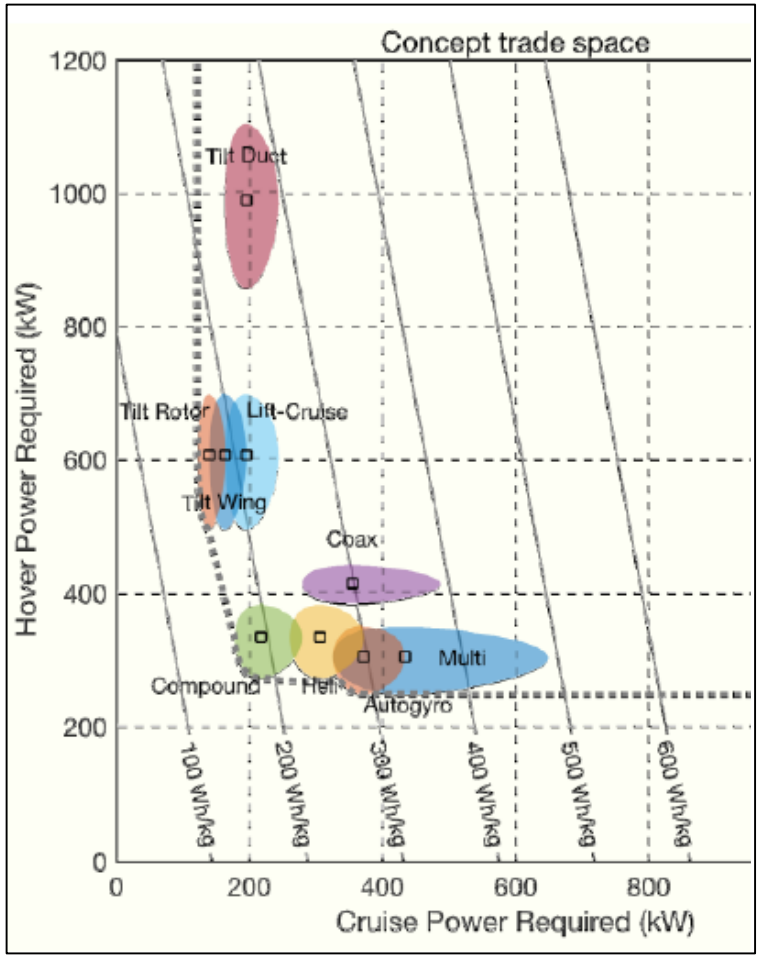
Power, Propulsion, Thermal, Airframe Integration





All components must integrate

eVTOL Power Required

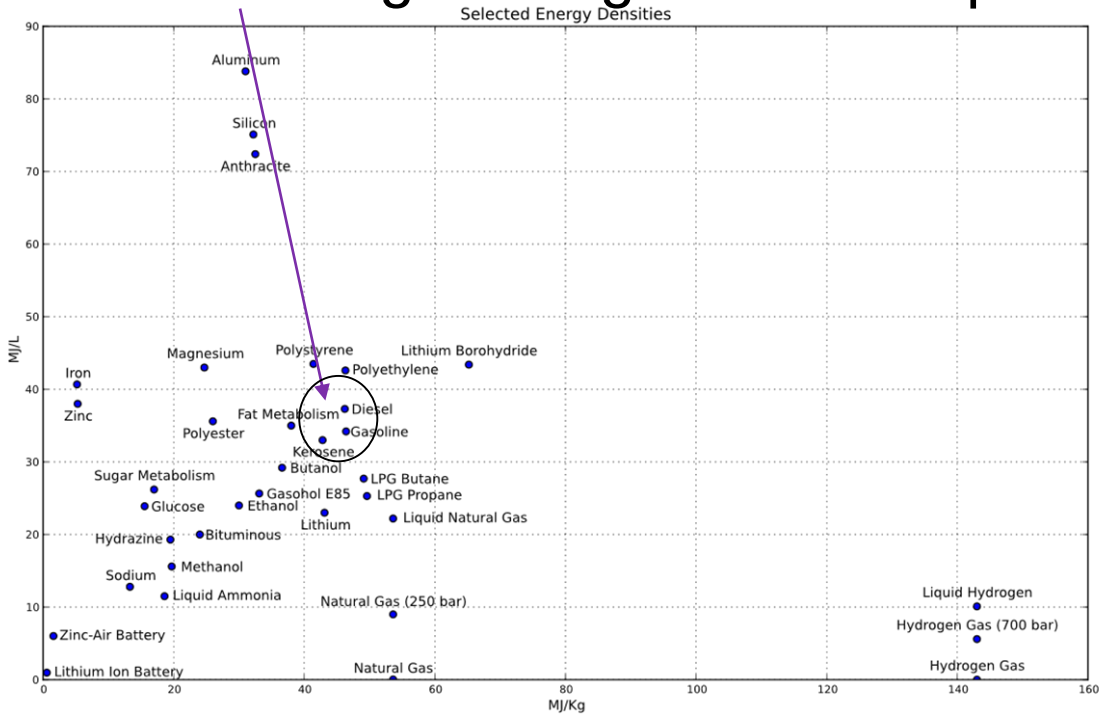


Aircraft Energy Options

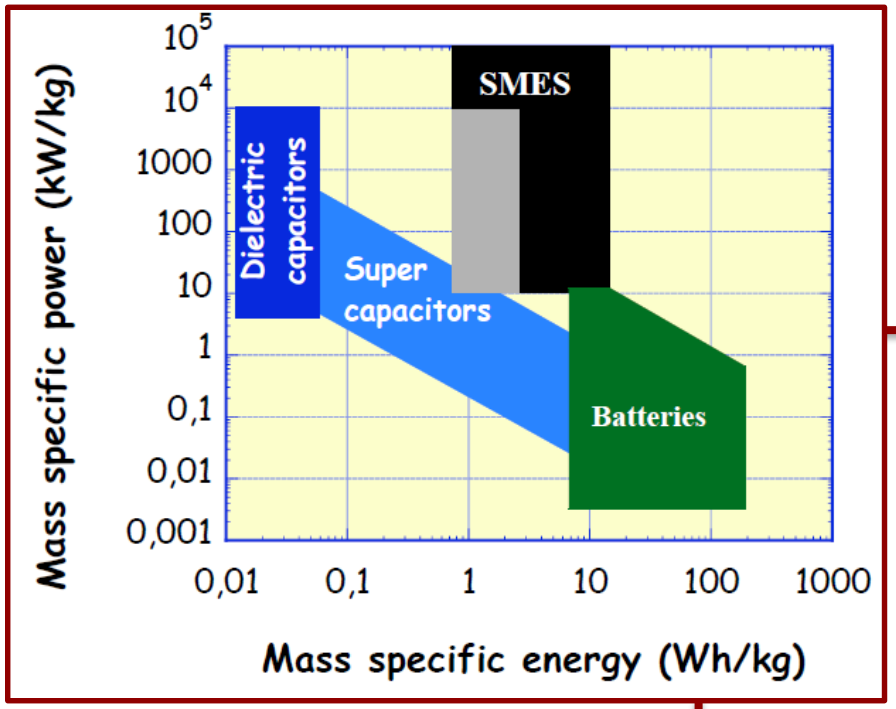
❑ 1 kg coal	8 kWh
❑ 1 kg wood	4 kWh
❑ 1 kg oil	10 - 12 kWh
❑ 1 kg natural gas	10 - 14 kWh
❑ 1 kg enriched uranium	600 000 kWh
❑ 1 kg of water - 1000 m fall	0.003 kWh ⬅
❑ 1 kg Pb battery	0.03 kWh
❑ 1 kg lithium battery	0.2 kWh

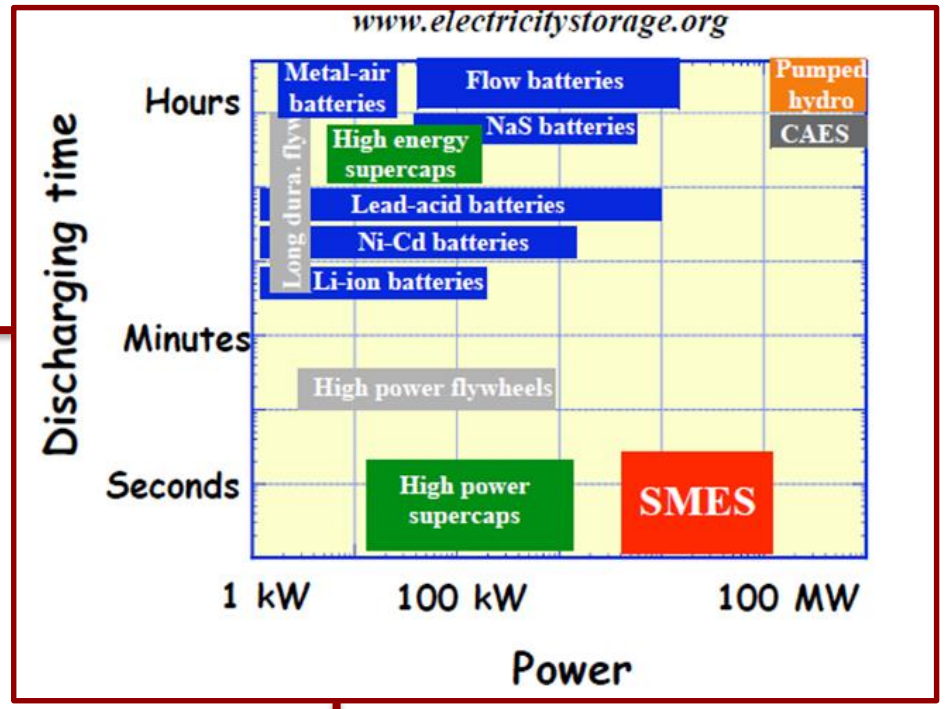
(1 kWh : kinetic energy of a 10 ton truck at 100 km/h)

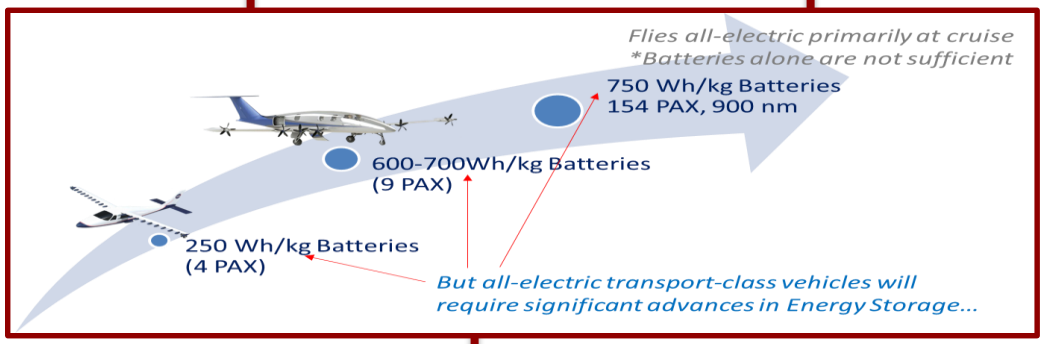
Jet Fuel is Light-Weight and Compact



Energy Storage

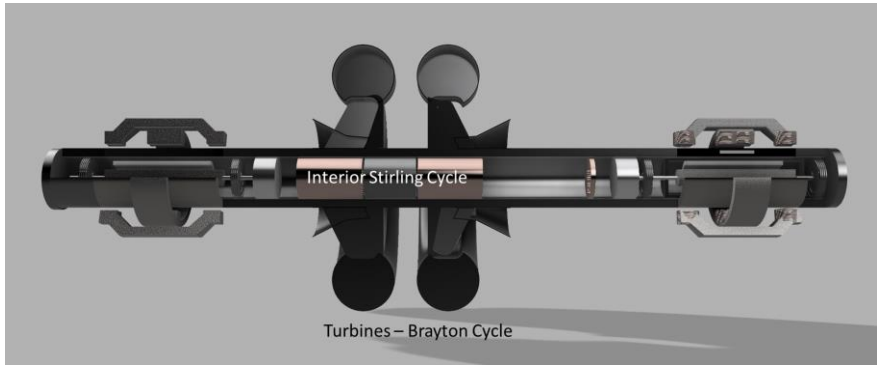


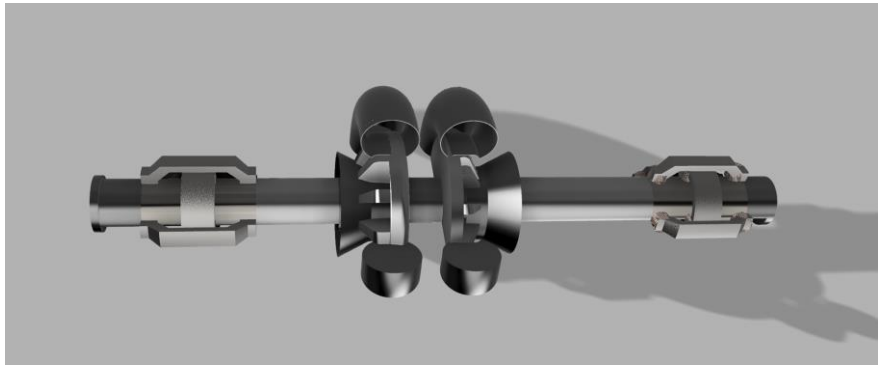


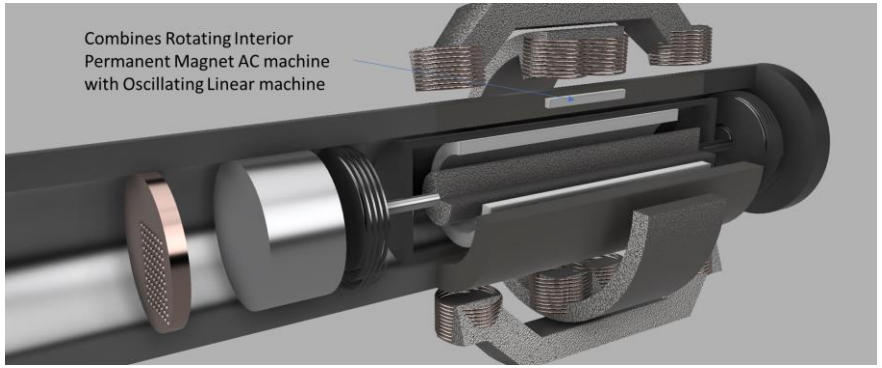


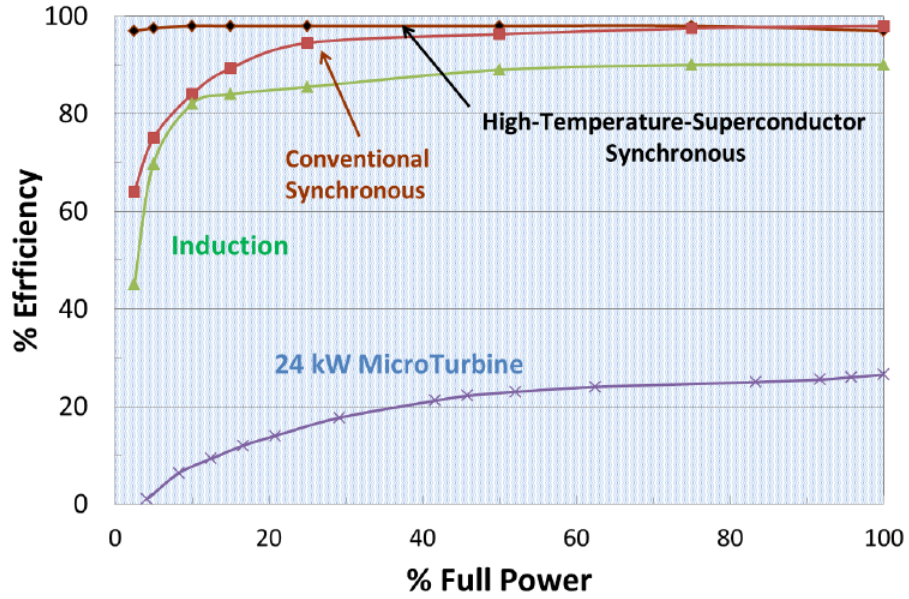
Can choose high energy or power, mass is a challenge

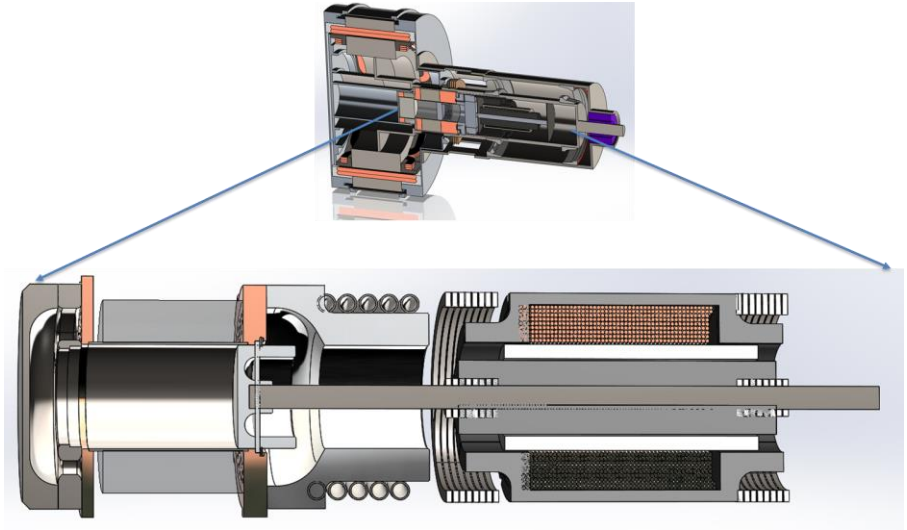
Turbo-electric Power Generation





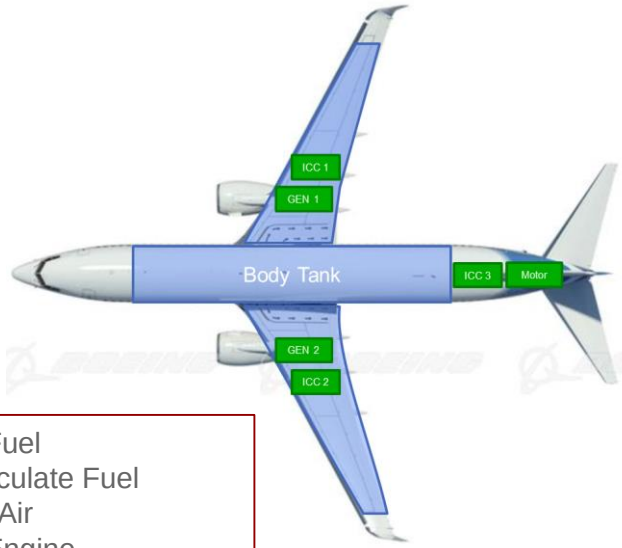




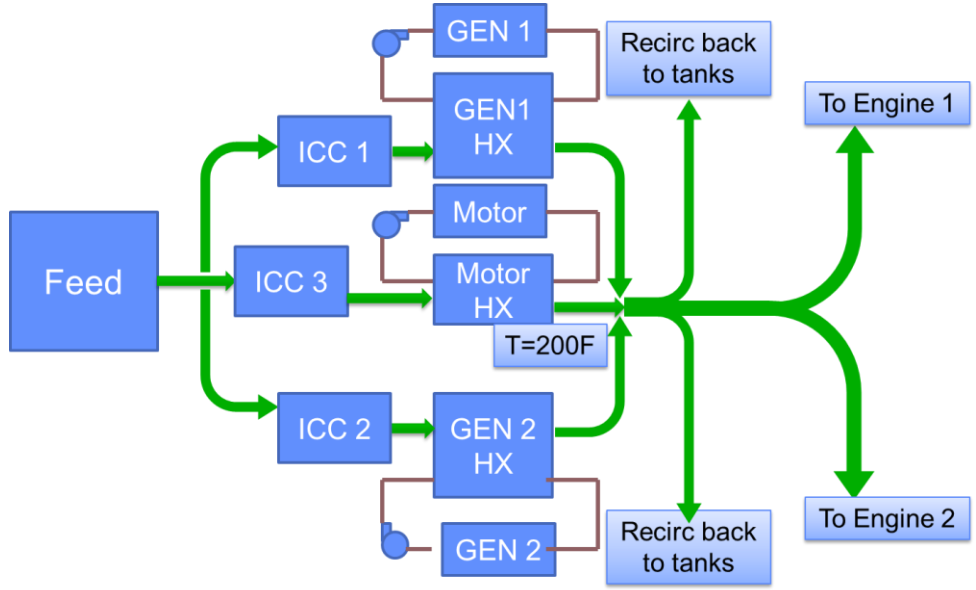


Stirling and Brayton (Strayton) Engine and Superconducting Motor

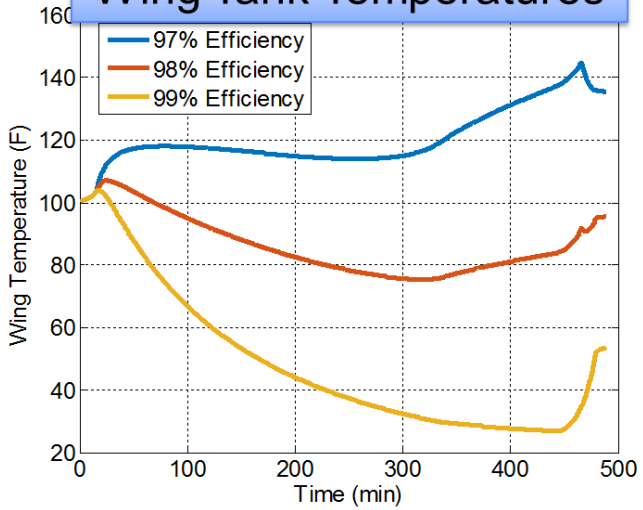
Thermal Limits



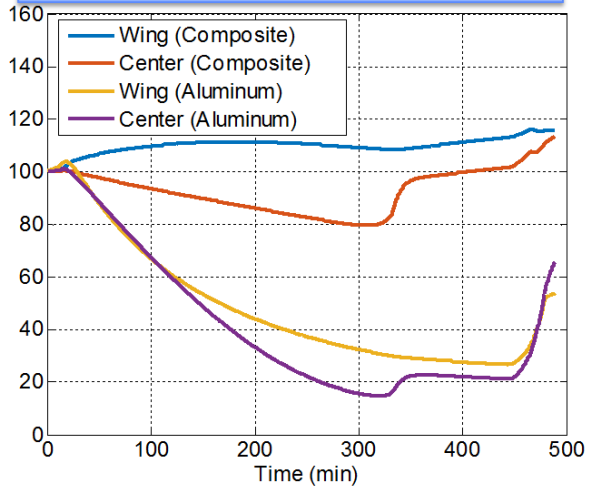
Into Fuel
Recirculate Fuel
Ram Air
Into Engine
Vapor-Compression



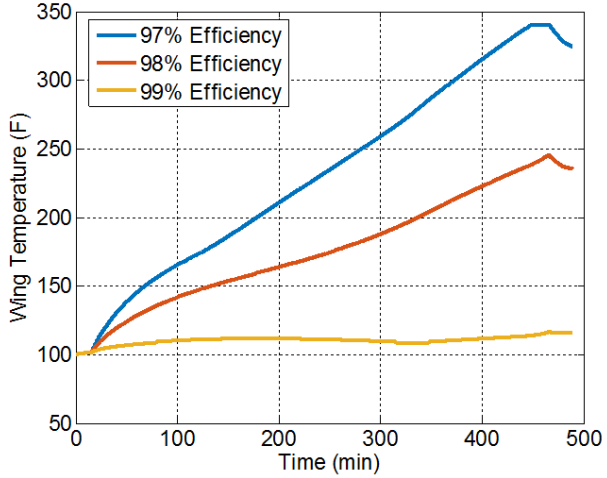
Wing Tank Temperatures



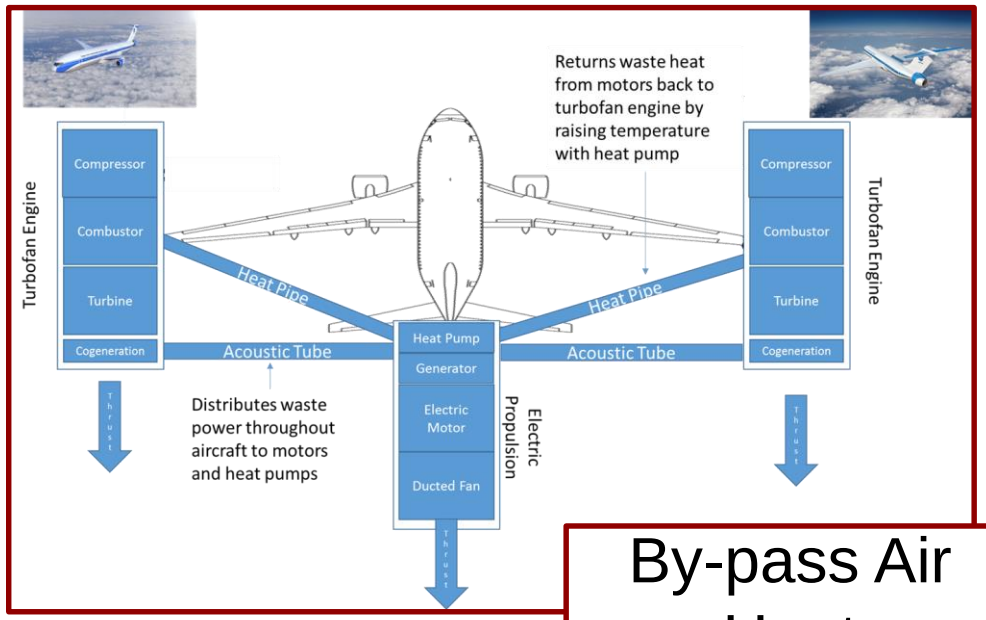
Tank Temperatures

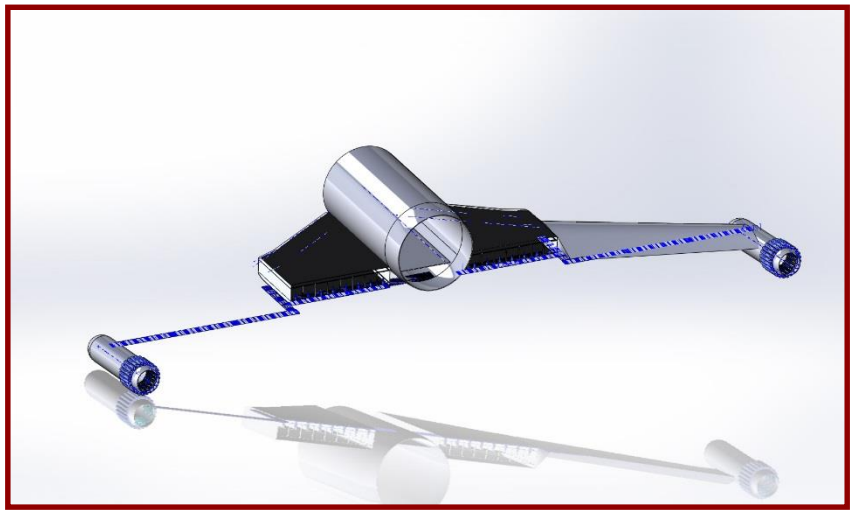


Thermal Runaway with Composite Fuselage



Thermal Energy Conversion and Recycling



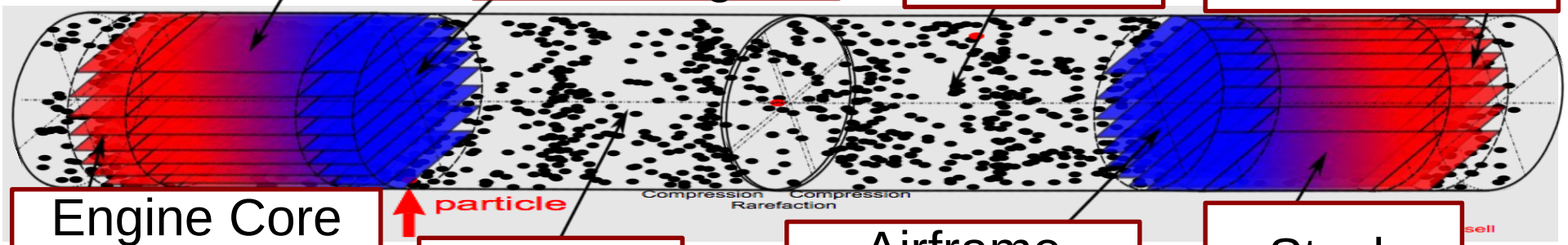


Stack

By-pass Air Heat Exchanger

Resonator

Heat Pipe Exchanger



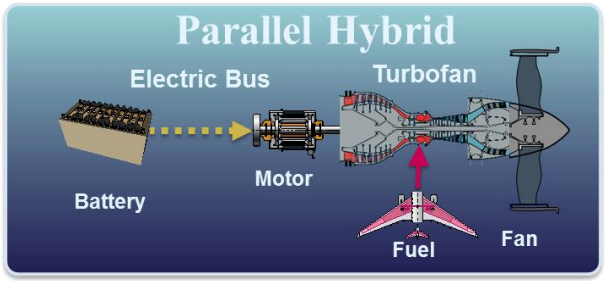
Engine Core Heat Exchanger

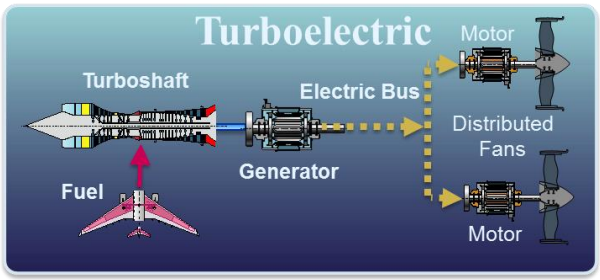
Resonator

Airframe Heat Exchanger

Stack

Technology Summary





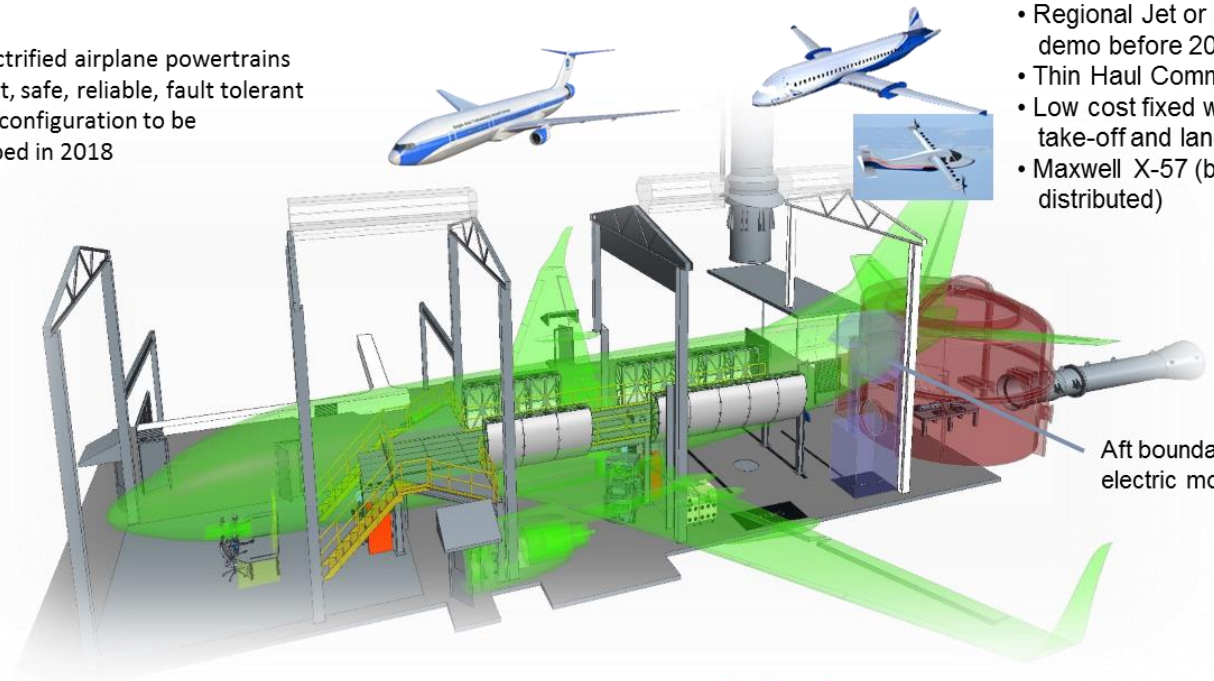
Technology: Vehicle and propulsion concepts and benefits studies

- Design and test electrified airplane powertrains that are flightweight, safe, reliable, fault tolerant
- NASA's STARC-ABL configuration to be tested in NEAT testbed in 2018 at full power

X-Planes: Near and Mid-term

- Regional Jet or Single Aisle demo before 2025
- Thin Haul Commuter
- Low cost fixed wing vertical take-off and landing (VTOL)
- Maxwell X-57 (battery, distributed)

Full-Scale Ground Tests:
NASA Electric Aircraft Testbed (NEAT)

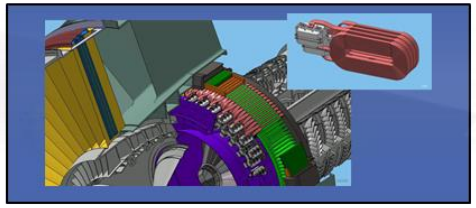


Aft boundary ingesting electric motor

Energy Storage	Electrical Distribution	Turbine Integration	Aircraft Integration
Battery Energy Density	High Voltage Distribution	Fan Operability with different shaft control	Stowing fuel & batteries; swapping batteries
Battery System Cooling	Thermal Mgt. of low quality heat	Small Core development and control	Aft propulsor design & integration
	Power/Fault Management	Mech. Integration	Integrated Controls
	Machine Efficiency & Power	Hi Power Extraction	
	Robust Power Elec.		
Parallel Hybrid Specific	**Common to Both**		**Turboelectric Specific**

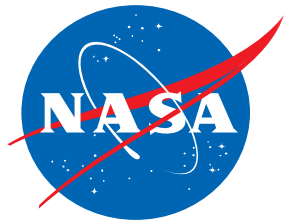
Technology: Powertrain Components

- Electric machines
- Power electronics
- Integrated turbines, generators
- Controls
- Transmission



Technology: Enabling Materials and Devices

- Insulation
- Conductors
- Magnetic materials
- Power electronics devices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